High Field Magnet Development

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High Field Magnet Program Goals

HFM Program is focused on the development of next generation SC accelerator magnets with high operating fields (>10 T at 4.5 K) and large operating margins for

- Tevatron
- LHC luminosity upgrade
- Future HEP facilities such as VLHC, etc.

This Program was started in 1998 and originally driven by a VLHC needs, which determined main magnet parameters such as field range, aperture, magnet design, etc. Since 2001 it is regarded as a generic SC magnet R&D program.

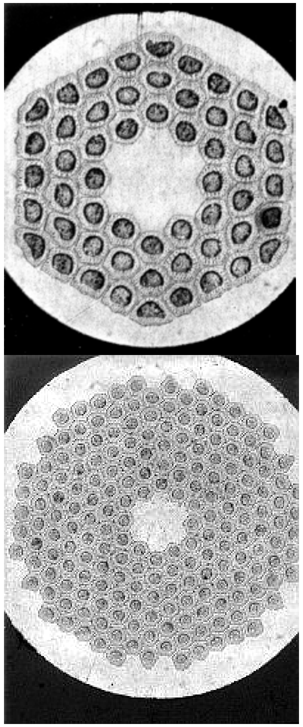
The specific feature of our program is that it focuses on practical magnet designs

- we worry about aperture and length, field quality, protection, manufacturability, cost, reproducibility, etc… not just peak field

Superconductor and Technologies

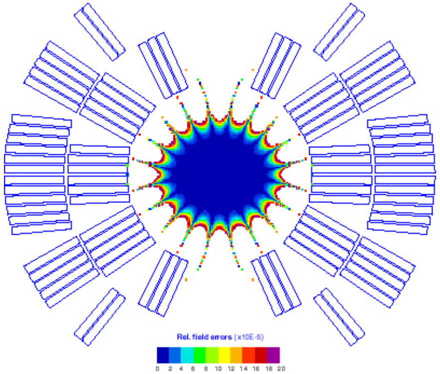
- At the present time we develop accelerator magnets based on Nb_3Sn superconductor
  - Critical parameters of Nb_3Sn (B_{c2}, T_c and J_c) are much higher than NbTi parameters
  - High-performance Nb_3Sn strands are commercially available in long lengths at affordable price
- We keep an eye also on other existing or new superconductors such as Nb_3Al, MgB_2, HTS, etc. which eventually may become potential candidates for accelerator magnets.
- Since most of the new superconductors including Nb3Sn are brittle, we explored two basic technologies for brittle superconductors:

Wind-and-React and React-and-Wind



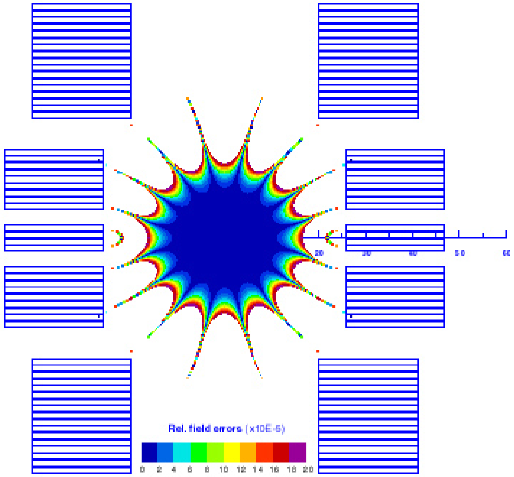
Nb3Sn strands produced using the IT and PIT technologies

Design Approaches



We worked with two basic dipole coil designs:

- **shell-type coils with a cos-theta azimuthal current distribution**
  - **Traditional coil design for SC accelerator magnets, due to small bending radii requires W&R approach**
- **block-type coils arranged in the common coil configuration**
  - **Friendly to brittle conductors thanks to large bending radii, allows R&W approach**



Both designs have advantages in different applications and both need to be studied and optimized.

We have accomplished first phase of R&W studies last year and now we focus on W&R technology.

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W&R Cos-Theta Dipole Models

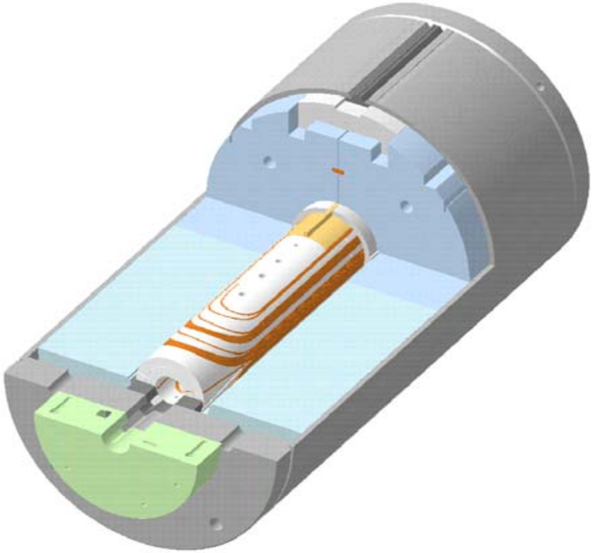
The goal of this work was to develop 10-11 T Nb_3Sn accelerator quality magnets based on the W&R technique.

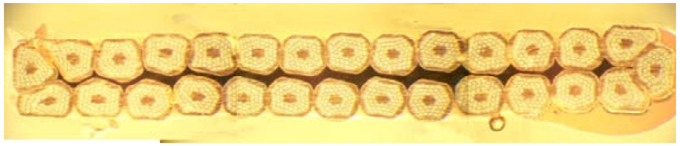
The main design features of 1-m long cos-theta Nb_3Sn dipole models (HFDA) are:

- **High-Jc 1-mm Nb_3Sn strand**
- **28 strand cable**
- **2-layer coil with cold iron yoke**
- **43.5-mm diameter bore**
- **Maximum field of 12 T at 4.5 K**

This design rests on the designs of the first Nb_3Sn dipole models developed in 1990s:

- **10 T dipole model (CERN/ELIN)**
- **11 T MSUT (Twente University)**
- **13 T D20 (LBNL)**





28-strand cable developed and fabricated at Fermilab

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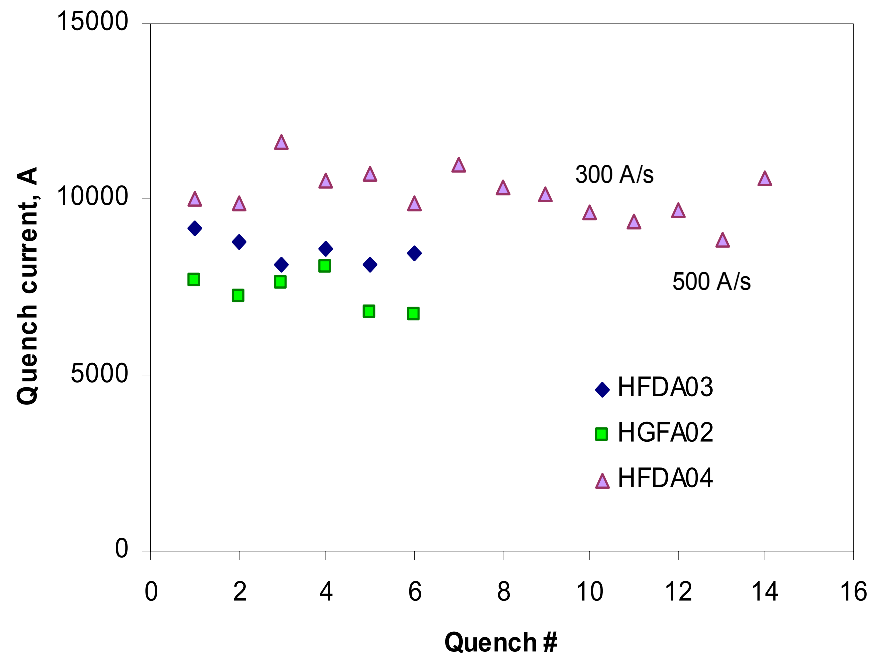
Cos-Theta Dipole Test Summary

Three short models (HFDA02-04) were fabricated and tested in FY2001-2002.

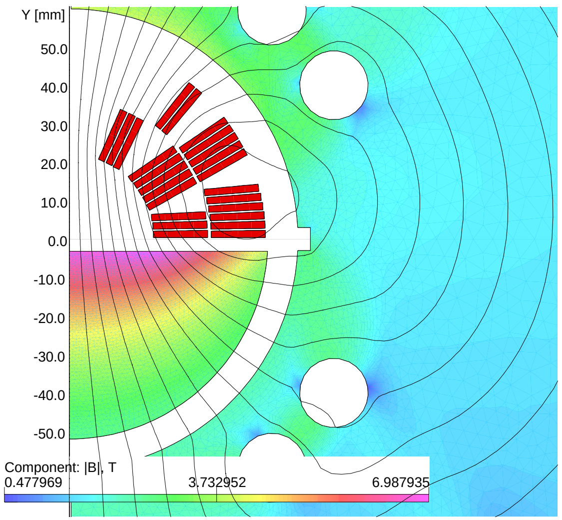
Results achieved:

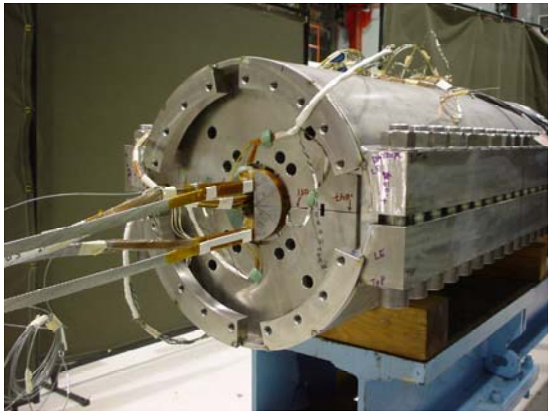
- **Good, well understood field quality including geometrical harmonics and coil magnetization effects**
  - **We developed and tested a simple and effective passive correction system to correct large coil magnetization effect in Nb_3Sn accelerator magnets**
- **Quench current was only 50-60% of expected short sample limit (B_{max}~6-7 T)**



Quench summary of HFDA short models

Magnetic Mirror





Since last year we have focused on understanding and improving magnet quench performance.

We study and optimize quench performance issues using half-coils and a magnetic mirror configuration (HFDM).

The main advantages of this approach are:

- **The same mechanical structure and assembly procedure**
- **Advanced instrumentation**
- **Shorter turnaround time**
- **Lower cost**

Coil and Cable Tests

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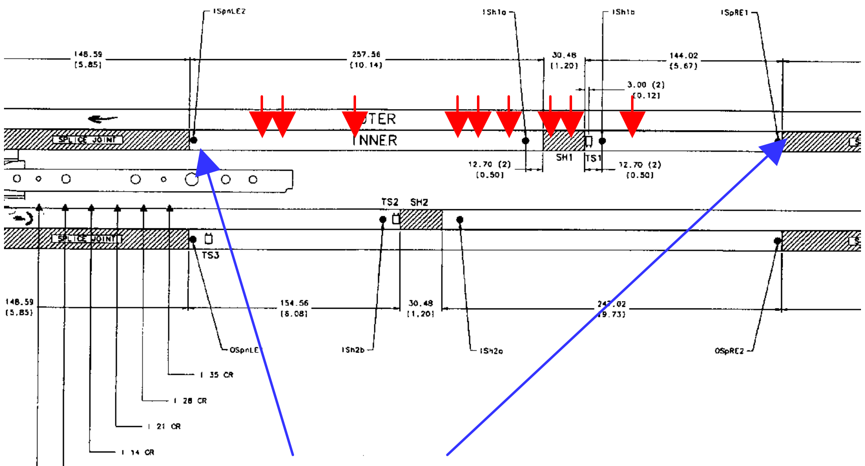
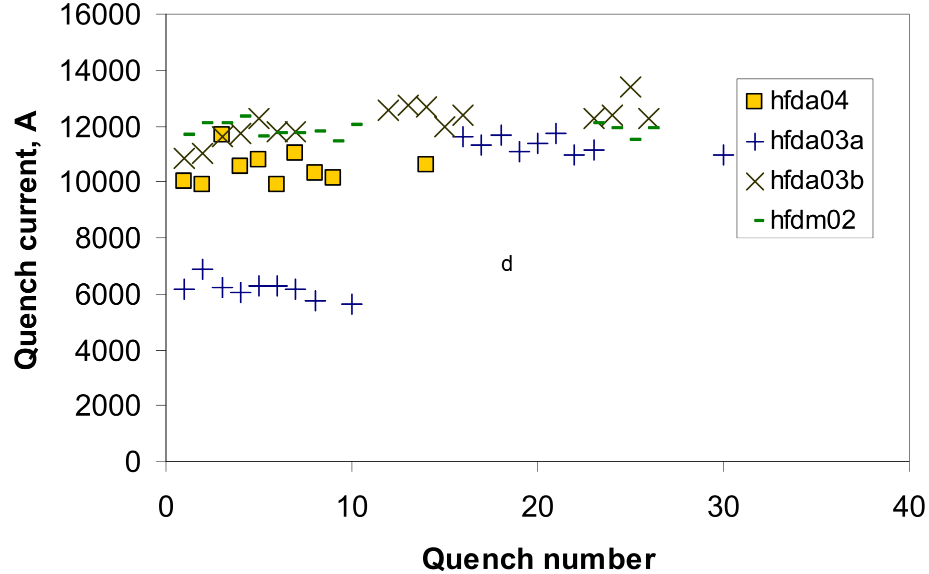
HFDA03b instrumentation and quench location



Cold quenches;
LHe bath temperature < 4.3K

Mirror magnet quench summary



Three mirror magnets have been tested last year:
•HFDA03a, HFDA03b, and HFDM02

Quench location, quench propagation velocity, critical current and temperature margin measurements point out on magnetic instability in Nb3Sn strands at low fields.

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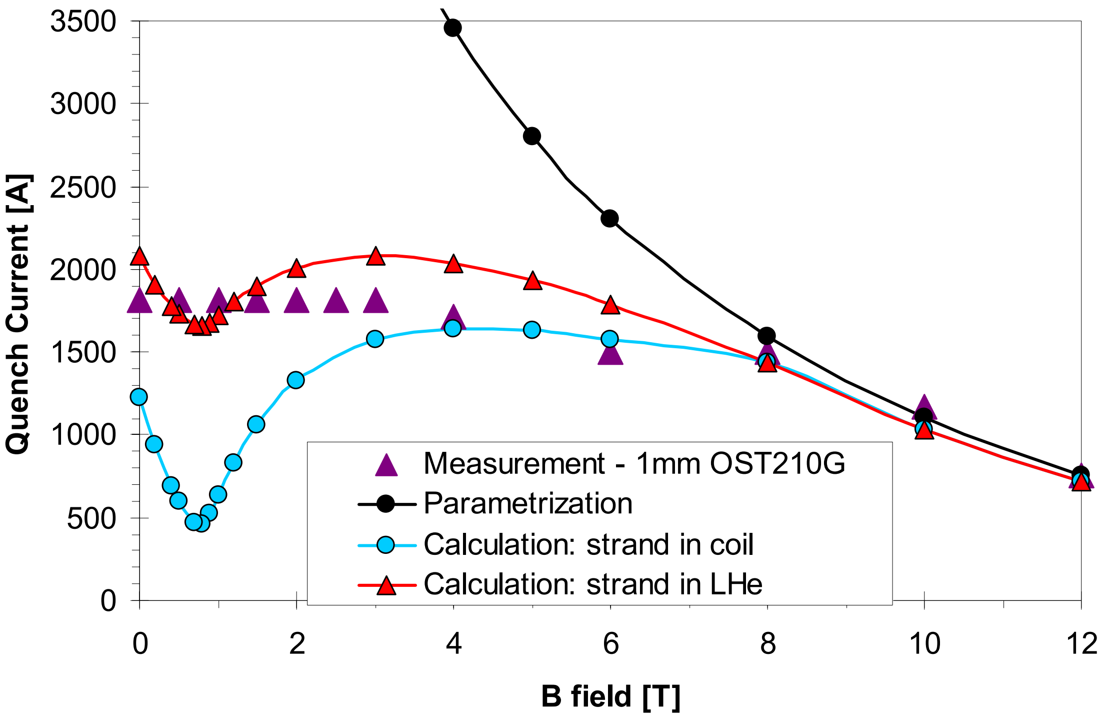
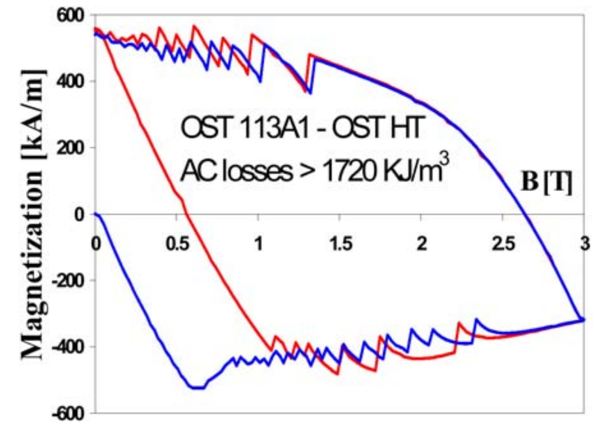
Strand Instability Studies





Instabilities in strand critical current and magnetization

Strand stability calculations and measurements revealed serious instability problems for the 1 mm MJR Nb3Sn strand used in our cos-theta dipole models.

Cable Short Sample Tests

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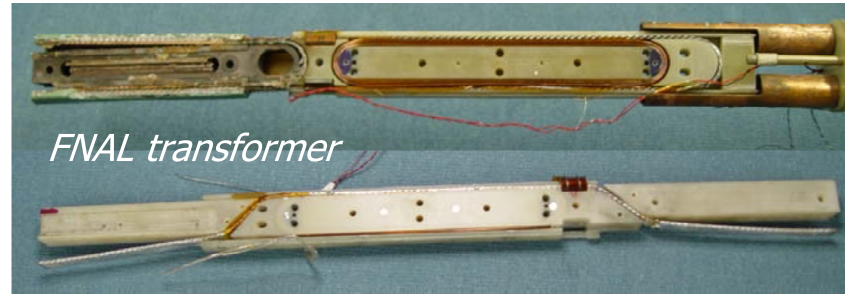
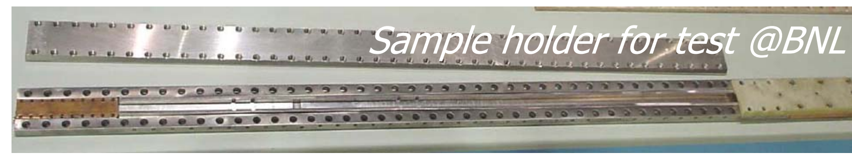
Fermilab:

- 23 kA SC Transformer, Bext=0T, T=1.9-4.2K

BNL:

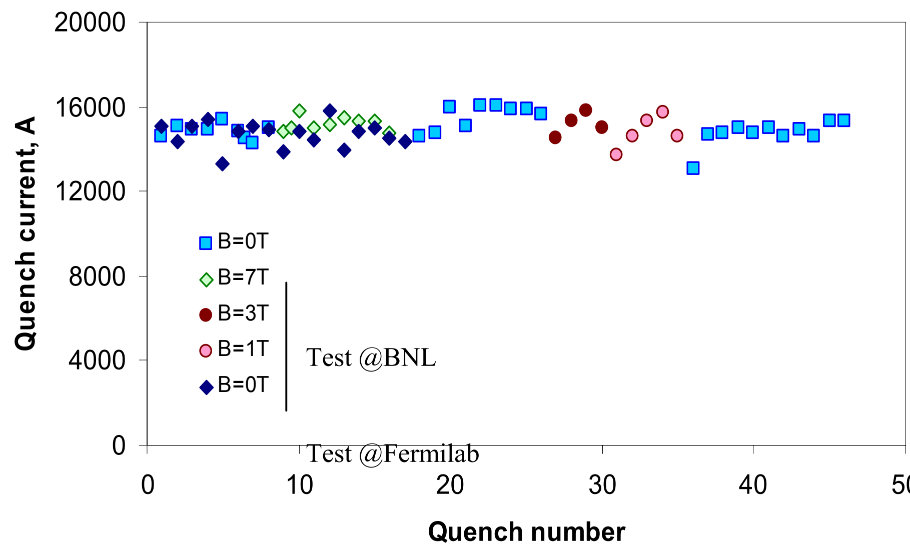
- 25 kA PS, Bext=0-7 T, T=4.3K





First results:

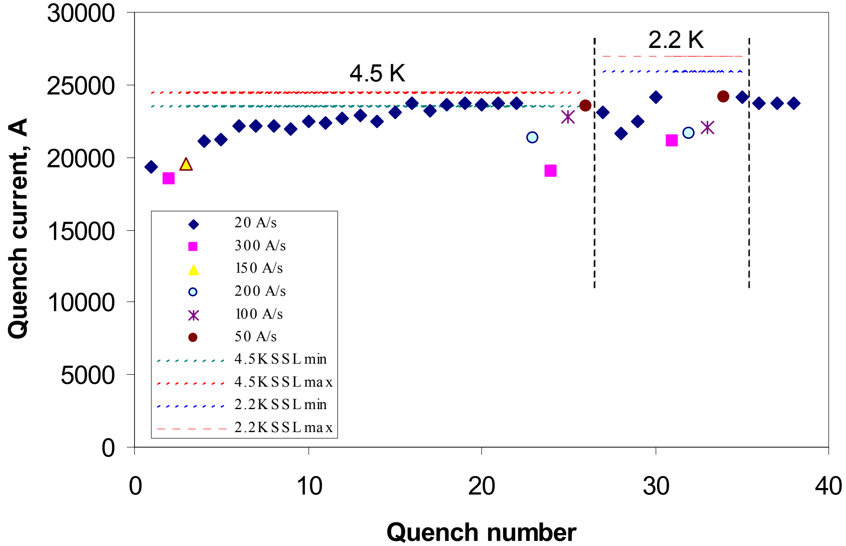
- Good agreement of experimental data obtained at Fermilab and BNL on similar samples in similar test conditions
- The results are consistent with Fermilab's instability model and magnet test results
- These tests will be continued

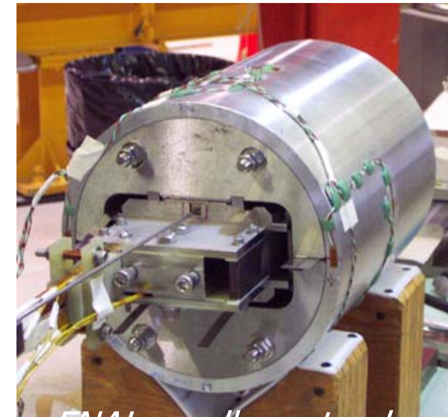


28 strand MJR-1.0mm cable tested at BNL and Fermilab

Small Racetracks

SR01 quench history





We test cable using the technique developed at LBNL.

The goals are:

- **Test and optimize real full-size cables before using in magnets**
- **Use simple reliable mechanical structure to avoid test setup effects**

- **1st (PIT1.0) Fermilab racetrack: tested in January-March 2004**
  - **Racetrack SR01 reached the short sample limit @4.5K (see quench history)**
- **2nd (MJR1.0) Fermilab racetrack: tests in April-May 2004.**

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Cos-theta Models

HFDM03:

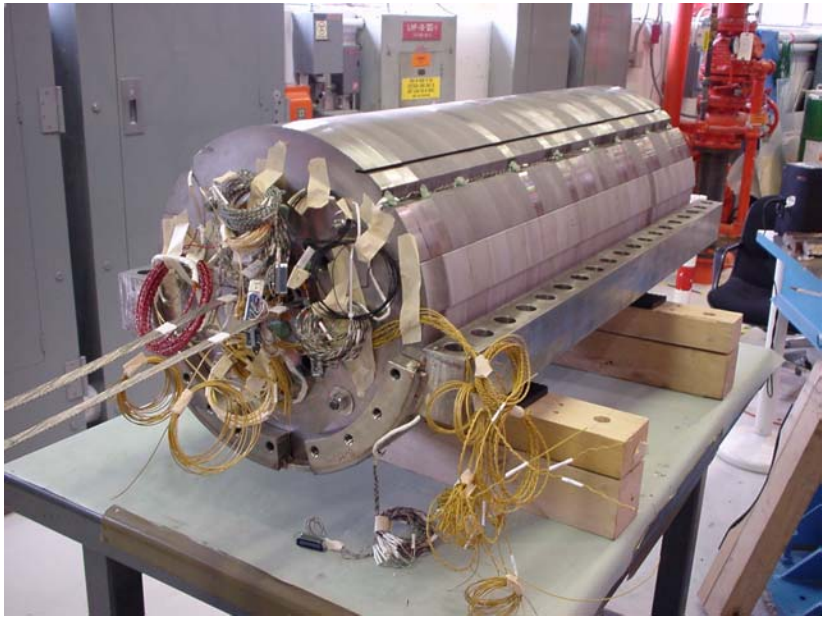
- **Mirror configuration**
- **PIT 1mm cable**
- **Optimized pre-stress**
- **Advanced instrumentation**

❖ **Fabrication has been completed**

❖ **test in April.**

❖ **Goals:**

- **Reach 10 T field level**
- **Test mechanical structure at high fields**



HFDM03 cold mass

Next steps:

❖ **Dipole model HFDA05:**

- **28-strand PIT 1mm cable w/o SS core (coil from HFDM03+new half-coil)**

❖ **Dipole model HFDA06:**

- **28-strand PIT 1mm cable with SS core (two new half-coils)**